(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 September 2003 (18.09.2003)

PCT

(10) International Publication Number
WO 03/077037 A1

(51) International Patent Classification: G03F 7/20

(21) International Application Number: PCT/EP03/01954

(22) International Filing Date: 26 February 2003 (26.02.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
102 10 899.4 8 March 2002 (08.03.2002) DE

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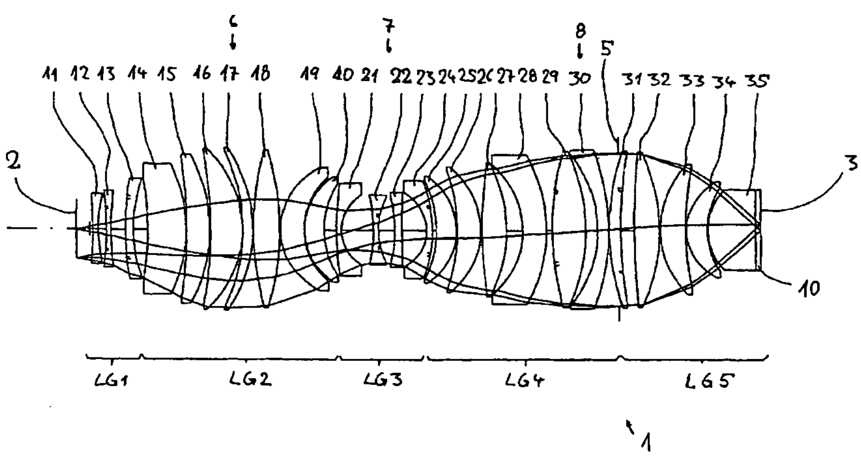
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

[Continued on next page]

(54) Title: REFRACTIVE PROJECTION OBJECTIVE FOR IMMERSION LITHOGRAPHY



(57) Abstract: A purely refractive projection objective suitable for immersion microlithography is designed as a single-waist system with five lens groups, in the case of which a first lens group with a negative refracting power, a second lens group with a positive refracting power, a third lens group with a negative refracting power, a fourth lens group with a positive refracting power and a fifth lens group with a positive refracting power are provided. The system aperture is in the region of maximum beam diameter between the fourth and the fifth lens group. Embodiments of projection objectives according to the invention achieve a very high numerical aperture of NA > 1 in conjunction with a large image field, and are distinguished by a good optical correction state and moderate overall size. Pattern widths substantially below 100 nm can be resolved when immersion fluids are used between the projection objective and substrate in the case of operating wavelengths below 200 nm.

WO 03/077037 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Description

Refractive projection objective for immersion lithography

The invention relates to a refractive projection objective for projecting a pattern arranged in an object plane of the projection objective into an image plane of the projection objective with the aid of an immersion medium which is arranged between a last optical element of the projection objective and the image plane.

Photolithographic projection objectives have been in use for several decades for producing semiconductor components and other finely structured structural elements. They serve the purpose of projecting patterns of photomasks or reticles, which are also denoted below as masks or reticles, onto an object coated with a photosensitive layer with very high resolution on a reducing scale.

Three developments running in parallel chiefly contribute to the production of every finer structures of the order of magnitude of 100 nm or below. Firstly, an attempt is being made to increase the image-side numerical aperture (NA) of the projection objective beyond the currently customary values into the region of NA=0.8 or above. Secondly, ever shorter wavelengths of ultraviolet light are being used, preferably wavelengths of less than 260 nm, for example 248 nm, 193 nm, 157 nm or below. Finally, still other measures are being used to increase resolution, for example phase-shifting masks and/or oblique illumination.

In addition, there are already approaches to improving the achievable resolution by introducing an immersion medium of high refractive index into the space between the last optical element of the projection objective and the substrate. This technique is denoted here as immersion lithography. Introducing the immersion medium yields an effective wavelength of

$$\lambda_{eff} = \lambda_0/n,$$

λ_0 being the vacuum operating wavelength and n the refractive index of the immersion medium. This yields a resolution of

$$R = k_1 (\lambda_{eff}/NA_0)$$

and a depth of focus (DOF) of

$$DOF = \pm k_2 (\lambda_{eff}/NA_0^2),$$

$NA_0 = \sin \Theta_0$ being the "dry" numerical aperture, and Θ_0 being half the aperture angle of the objective. The empirical constants k_1 and k_2 depend on the process.

The theoretical advantages of immersion lithography reside in the reduction of the effective operating wavelength and the resolution improved thereby. This can be achieved in conjunction with an unchanged vacuum wavelength, and so established techniques for producing light for selecting optical materials, for coating technology etc. can be adopted largely without change for the appropriate wavelength. However, measures are required for providing projection objectives with very high numerical apertures in the region of NA = 1 or above. Furthermore, suitable immersion media must be available.

The article entitled "Immersion Lithography at 157 nm" by M. Switkes and M. Rothschild, J. Vac. Sci. Technol. Vol. 19 (6), Nov./Dec. 2001, pages 1 ff. presents immersion fluids based on perfluoropolyethers (PFPE) which are sufficiently transparent for a working wavelength of 157 nm and are compatible with some photoresist materials currently being used in microlithography. One tested immersion fluid has a

refractive index of n = 1.37 at 157 nm. The publication also describes a lens-free optical system, operating with calcium fluoride elements and silicon mirrors, for immersion interference lithography, which is intended to permit the projection of 60 nm structures and below in conjunction with a numerical aperture of NA = 0.86. The optical system may not be suitable for use in the series production of semiconductors or the like.

Patent Specification US 5,610,683 (corresponding to EP 0 605 103) describes a projection exposure machine, provided for immersion lithography, having devices for introducing immersion fluid between the projection objective and the substrate. No design is specified for the optical projection system.

US Patent US 5,900,354 proposes using a super-critical fluid, for example xenon gas, as immersion medium in immersion lithography. No design is shown for a suitable projection objective.

It is the object of the invention to create a refractive projection objective which is suitable for immersion lithography and which has, in conjunction with a moderate overall size, a high numerical aperture suitable for immersion lithography, an image field which is sufficiently large for practical use in wafer steppers or wafer scanners, and a good correction state.

This object is achieved by means of a projection objective having the features of Claim 1. Advantageous embodiments are specified in the dependent claims. The wording of all the claims is incorporated in the description by reference.

In accordance with one aspect of the invention, a refractive projection objective for projecting a pattern arranged in an object plane of the projection objective into the image plane of the projection objective with

the aid of an immersion medium which is arranged between a last optical element of the projection objective and the image plane has
a first lens group, following the image plane, with a negative refracting power;
a second lens group, following thereupon, with a positive refracting power;
a third lens group, following thereupon, with a negative refracting power;
a fourth lens group, following thereupon, with a positive refracting power;
a fifth lens group, following thereupon, with a positive refracting power; and
a system aperture which is arranged in the region of maximum beam diameter between the fourth lens group and the fifth lens group.

This refracting power distribution produces a projection objective having two bellies and a waist therebetween, a good correction of the field curvature thereby being achieved. The system aperture is seated in the region of greatest beam diameter of the belly next to the image plane, preferably at least 90% or 95% of the maximum beam diameter being present in the belly near the image at the location of the system aperture. In certain embodiments, the system aperture can lie between a plane of maximum beam diameter near the image and the image plane, and thus in a region in which the transilluminated diameter of the objective already decreases towards the image plane. This is a substantial difference from conventional, refractive projection objectives in which the system aperture lies on the object side at a relatively large distance in front of the region of maximum beam diameter in the belly near the image.

The design permits image-side numerical apertures $NA \geq 0.9$, it being possible in the case of preferred embodiments to achieve $NA = 1.1$ or above. Preferred projection objectives are adapted to an immersion fluid which has a refractive index of $n > 1.3$ at the operating wavelength. As a

result, a reduction in the effective operating wavelength by 30% or more can be achieved by a comparison with systems without immersion.

The projection objective can advantageously be designed such that the space to be filled up by the immersion medium has an axial thickness which is so small that transmission losses in the immersion medium are no more than 10 to 20% of the penetrating light intensity. Consequently, image-side working distances of less than 200 μm, in particular less than 100 μm, are favourable. Since, on the other hand, touch contact between the last optical element and the substrate surface is to be avoided, a lower limit for the working distance of from 10 to 20 μm should not be undershot. Larger working distances in the region of one or more millimeters are also possible given suitably transparent immersion media.

Preferred projection objectives are distinguished by a number of favourable structural and optical features which are necessary alone or in combination for the suitability of the objective as an immersion objective.

For example, it can be favourable when the refracting powers of the lens groups are of the same order of magnitude on both sides of the system aperture. In particular, it can be provided that a ratio between the focal length of the fourth lens group and the focal length of the fifth lens group is between approximately 0.9 and approximately 1.1. It can likewise be favourable when the focal lengths or refracting powers of the lens groups near the object and lens groups near the image are similar in magnitude. In particular, a ratio of the magnitudes of the focal lengths of the first lens group and the fifth lens group can be between approximately 0.7 and approximately 1.3, preferably between approximately 0.9 and 1.1. Furthermore, it can be favourable for

producing a high image-side numerical aperture when a strong positive refracting power is concentrated in the region near the image. In preferred embodiments, a ratio between the overall length of the projection objective and the focal length of the fifth lens group following the system aperture is greater than five, in particular greater than six, seven or even eight. The axial distance between the object plane and image plane is denoted here as overall length.

In order to achieve a good correction state, it is provided in preferred embodiments that the first lens group includes at least one aspheric surface. Favourably, it is even possible for a plurality of aspherics, for example two, to be provided here. Aspherics in this region make a particularly effective contribution to the correction of distortion and astigmatism. It is favourable, furthermore, for the correction of coma and astigmatism when the third lens group, situated in the region of the waist, has at least one aspheric surface, a plurality of aspherics, for example two aspherics, being preferred. In the case of preferred embodiments, at least one aspheric is provided in each lens group in order to facilitate fine setting of the correction state of the projection objective. With regard to simple production of the lenses, the number of aspherics should be limited, for example to less than nine or less than seven, as in the case of a preferred embodiment.

The favourable projection properties of projection objectives according to the invention, particularly the good correction state in the case of a very high numerical aperture, are promoted by some special features relating to the type and arrangement of the lenses used. For example, it is favourable when at least one meniscus lens, convex relative to the object plane, with a negative refracting power is arranged in the near zone of the object plane, in particular in the first lens group. This lens, which can form the third lens of the objective, for example, favours the correction of tangential astigmatism.

The second lens group preferably has at least one, in particular a plurality of meniscus lenses, concave relative to the object plane, with a positive refracting power on its side facing the object plane. These preferably combine with at least one, preferably a plurality of meniscus lenses, convex relative to the object plane, with a positive refracting power on the side, facing the image plane, of the second lens group. At least one biconcave positive lens is favourably situated between the menisci or meniscus groups of the opposing bending. As a result, a sequence of at least one positive meniscus lens, concave relative to the object plane, a biconvex positive lens and at least one positive meniscus lens, concave relative to the image plane, can be formed in the second lens group. This sequence of lenses in the region of relatively large beam diameter of the first belly is favourable for a strong "deformation" of the main ray in this region in conjunction with low areal stresses of the optical surfaces. This is favourable for low total aberrations of the projection objective. A favourable areal stress in the sense of this application occurs whenever the incidence angles of the rays striking an optical surface are as small as possible and do not overshoot a critical limit value. Denoted here as incidence angle is the angle between the impingement direction of a ray on an optical surface and the surface normal of the optical surface at the impingement point of the ray. The smaller the incidence angle and, correspondingly, the lower the areal stress, the easier is the development of suitable antireflection coatings, and the greater is the tolerance of the design to the adjustment.

The region of narrowest constriction of the ray is denoted as the waist. The third lens group in the region of the waist has the task of re-expanding the radiation, converging downstream of the first belly, with as few aberrations as possible. It is favourable for this purpose when the third lens group has only lenses with a negative refracting power. It has proved to be particularly advantageous when, with reference to a plane of symmetry lying inside the third lens group, the third lens group is of

substantially symmetrical construction. This is distinguished, in particular, by virtue of the fact that mutually assigned lenses of the same type are arranged on the object side and image side of the plane of symmetry. The symmetry of the lens types preferably also extends into the bordering region of the second and fourth lens groups such that an exit region, facing the third lens group, of the second lens group, and an entry region, following the third lens group, of the fourth lens group can be constructed substantially symmetrically relative to the plane of symmetry lying inside the third lens group. A symmetrical arrangement of negative and positive meniscus lenses will be explained in further detail in conjunction with the embodiments. The symmetry promotes a low areal stress of the lenses in conjunction with few aberrations.

At least one doublet with a biconvex positive lens and a meniscus-shaped negative lens, following towards the image, with lens surfaces which are concave towards the object is preferably provided in the region directly upstream of the system aperture, that is to say in the fourth lens group. Particularly favourable are embodiments having two such doublets which can follow one another directly. A positive air lens, convex relative to the image plane, is respectively arranged between the lenses of the doublet. Such doublets composed of a collecting biconvex lens and a diverging meniscus have a positive effect on the correction state and can counteract the aberrations which are introduced by lenses with a strong, positive diffracting power downstream of the system aperture. It can be favourable, moreover, to arrange in the object-side entry region of the fourth lens group at least one meniscus lens, concave towards the object, with a positive refracting power, in order to collect the radiation coming from the waist in conjunction with a low areal stress.

In order to achieve very high numerical apertures, it is advantageous when the fifth lens group has exclusively positive lenses. It is possible,

for example, to arrange four or more positive lenses between aperture stop and image plane. In this case, favourable surface loads can be achieved whenever at least one meniscus lens, concave towards the image, with a positive refracting power is provided in the fifth lens group. In particular, two or more such lenses can be provided. The last optical element is preferably formed by a plano-convex lens which preferably has a spherical entry surface and a substantially flat exit surface. It is possible thereby, on the one hand, to achieve a good correction of spherical aberration and coma and, on the other hand, a substantially flat exit surface is favourable for immersion lithography. In preferred embodiments, the plano-convex lens is nonhemispherical, the centre of the spherical surface lying outside the lens. Truncated hemispherical lenses of this type can yield a reduced sensitivity to fluctuations in the working distance.

By applying some or all of these design principles, success has been achieved in preferred embodiments which keep the surface loads of the lenses so low that despite an aperture of more than NA = 0.9 or 1, incidence angles whose sine is greater than approximately 90% or even approximately 85% of the image-side numerical aperture do not occur at any of the optical surfaces, and this simplifies the coating of the lenses and the adjustment of the objective.

In preferred embodiments, all the lenses of the projection objective consist of the same material. For operating wavelengths of 193 nm, synthetic quartz glass and, for operating wavelengths of 157 nm, calcium fluoride can be used, for example, as material. The use of only one kind of material facilitates production and permits simple adaptation of the objective design to other wavelengths. It is also possible to combine a plurality of kinds of material in order, for example, to support the correction of chromatic aberrations. It is also possible to use other UV-transparent materials such as BaF_2, NaF, LiF, SrF, MgF_2 or the like.

In addition to the claims, the description and the drawings also disclose the preceding and further features, it being possible for the individual features to be implemented on their own or severally in the form of subcombinations in the case of embodiments of the invention and in other fields, and for them to constitute advantageous designs which can be protected per se. In the drawings:

Figure 1 shows a lens section through a first embodiment of a refractive projection objective which is designed for a 193 nm operating wavelength;

Figure 2 shows a lens section through a second embodiment of a projection objective which is designed for a 193 nm operating wavelength;

Figure 3 shows a lens section through a third embodiment of a projection objective which is designed for a 157 nm operating wavelength; and

Figure 4 shows a lens section through a fourth embodiment of a projection objective which is designed for a 193 nm operating wavelength.

In the following description of preferred embodiments, the term "optical axis" denotes a straight line through the centres of curvature of the optical components. Directions and distances are described as on the image side or towards the image when they are aligned in the direction of the image plane or the substrate, which is to be exposed, located there, and as on the object side or towards the object when they are directed towards the object with reference to the optical axis. In the examples, the object is a mask (reticle) with the pattern of an integrated circuit, but it can also be another pattern, for example a grating. In the

examples, the image is formed on a wafer which serves as a substrate and is provided with a photoresist layer, but other substrates are also possible for example elements for liquid crystal displays or substrates for optical gratings. The focal lengths specified are focal lengths with reference to air.

Identical or mutually corresponding features of the various embodiments are denoted below with the same reference symbols for reasons of clarity.

A typical design of an embodiment of a purely refractive reduction objective 1 according to the invention is shown with the aid of Figure 1. It serves the purpose of projecting in conjunction with virtually homogeneous immersion a pattern, arranged in an object plane 2, of a reticle or the like into an image plane 3 to a reduced scale, for example to the scale of 5:1. This is a rotationally symmetrical single-waist system with five lens groups which are arranged along the optical axis 4, which is perpendicular to the object plane and image plane, and form an object-side belly 6, an image-side belly 8 and a waist 7 situated therebetween. The first lens group LG1, following the image plane 2, has a negative refracting power and a focal length of -166 mm. A second lens group LG2, following thereupon, has a positive refracting power with a focal length of 121 mm. A third lens group LG3, following thereupon, has a negative refracting power and a focal length of -33 mm. A fourth lens group LG4, following thereupon, has a positive refracting power with a focal length of 166 mm, which therefore corresponds in terms of magnitude to the focal length of the first lens group. A fifth lens group LG5, following thereupon, has a positive refracting power and a focal length of 170 mm, which is of the order of magnitude of the focal length of the fourth lens group and of the first lens group LG1 in terms of magnitude. The system aperture 5 is arranged between the fourth lens group LG4 and the fifth lens group LG5 in the

region, near the image, of maximum beam diameter, that is to say in the second belly 8 of the objective.
The first lens group LG1, following the object plane 2, is substantially responsible for the expansion of the light bundle into the first belly 6. It comprises three lenses 11, 12, 13 with a negative refracting power, the first lens 11 and the second lens 12 being configured as biconvex negative lenses. The third lens 13 is a diverging meniscus in the case of which as a special feature the concave side is directed not towards the object 2 but towards the image plane 3. This arrangement is very favourable for correcting the tangential astigmatism. Otherwise, the first lens group includes two aspherics, specifically the entry sides of the second and the third lens. The aspherics have a positive influence on the very good correction of the distortion and the astigmatism.

The second lens group LG2 comprises four collecting menisci 14, 15, 16, 17, facing the reticle or the object plane 2 with their concave side, a biconvex positive lens 18 and two collecting menisci 19, 20 facing the wafer or the image plane 3 with their concave side. This design, in which the curvatures of the meniscus surfaces run on the object side and image side of the biconvex lens 18 in opposite directions with concave surfaces averted from one another, ensures small areal stresses for the menisci and the positive lens 18, and thus few aberrations. The biconcave air lens between the biconvex positive lens 18 and the following meniscus lens 19 has with its strong astigmatic undercorrection a favourable influence on the balancing-out of the astigmatism in the front part of the system upstream of the waist 7.

The third lens group LG3 consists exclusively of diverging lenses, specifically a negative meniscus lens 21 with image-side concave surfaces, a biconcave negative lens 22, following thereupon, a further biconcave negative lens, following thereupon, and a negative meniscus lens 24, following thereupon, with object-side concave surfaces. With

reference to a plane of symmetry 9 lying between the lenses 22 and 23, these four lenses are designed with mirror symmetry with regard to lens type (meniscus lens or biconcave lens) and direction of curvature of the optical surfaces. Together with the last two lenses 19, 20 of the second lens group and the first two lenses 25, 26 of the fourth lens group LG4, following thereupon, there is a series of two collecting menisci 19, 20 and one diverging meniscus 21, all three of which have concave surfaces facing the waist or the plane of symmetry 9. In the opposite, mirrored direction, that is to say on the image side of the plane of symmetry 9, the two biconcave negative lenses 22, 23 are again followed at the waist, that is to say in the area of smallest diameter, by a diverging meniscus 24 and two collecting menisci 25, 26 of the fourth lens group. This design having mirror symmetry relative to the plane of symmetry 9 supports a low tensioning or a low areal stress of the optical surfaces, and thus few aberrations.

The third lens group includes, in the form of the exit surface of the smallest lens 22 and the exit surface of the negative meniscus lens 24, two aspherics which make a substantial contribution to the correction of the coma and the astigmatism.

The fourth lens group LG4 comprises on its entry side two positive meniscus lenses 25, 26 which are concave relative to the object plane and are followed by two doublets 27, 28 and 29, 30. Each of the doublets has, on the object side, a collecting biconvex lens 27 and 29, respectively, and downstream thereof a diverging meniscus 28 and 30, respectively, whose concave surfaces point towards the object plane. The two spherically strongly overcorrected, diverging menisci 28 (f' = -728 mm) and 30 (f' = -981 mm) counteract the strongly undercorrected, collecting lenses of the fifth lens group LG5 following downstream of the system aperture 5. The combination of the collecting biconvex lens and the diverging meniscus inside a doublet has a very positive effect on the

correction of image errors in the region of the second belly 8. With their strong overcorrection of the tangential astigmatism, the two menisci 28, 30, in particular the thick meniscus 28, counteract the undercorrection in the fifth lens group LG5.

The fifth lens group LG5, situated downstream of the system aperture 5, is substantially responsible for producing the high numerical aperture. Provided for this purpose are exclusively collecting lenses, specifically a positive meniscus lens 31, arranged in the region of the system aperture 5, with surfaces concave towards the image, a biconvex positive lens 32, following thereupon, with a slightly curved entry side and a more strongly curved exit side, a positive meniscus lens 23, following thereupon, with surfaces concave towards the image, a further positive meniscus lens 24, likewise with surfaces concave towards the image, and a terminating plano-convex lens 35 with a spherical entry side and a flat exit side. The positive lenses 31, 32, 33 and 34 are strongly undercorrected spherically and overcorrected with reference to the coma. In the case of this design, the correction of the spherical aberration and the coma is therefore implemented substantially in conjunction with the configuration of the fourth lens group LG4 which is situated upstream of the system aperture 5 and creates a corresponding offset of these aberrations.

Consequently, the fourth lens group LG4 and the fifth lens group LG5 are responsible in combination for achieving a good correction state of the spherical aberration and of coma. An aspheric surface on the entry side of the biconvex lens 27 of the first doublet substantially supports the correction of the spherical aberration, but also of the coma of third order. An aspheric surface, arranged in the vicinity of the system aperture 5, on the exit side of the positive meniscus lens 31, convex towards the object, at the input of the fifth lens group LG5 chiefly corrects aberrations of higher order and thereby makes a substantial contribution to setting a good aberration compromise. A likewise positive influence on the

correction of aperture aberration and coma is exerted by the spherical, convex entry surface of the plano-convex lens 35. The latter is spherically overcorrected and undercorrected with reference to coma.

The system has a working distance on the image side of approximately 8.4 mm, which can be filled up by an immersion fluid 10. Deionized water (refractive index n = 1.47) or another suitable transparent liquid, for example, can be used at 193 nm as immersion fluid.

The correction state of the optical system 1 is excellent. All aberrations are corrected. The RMS value of the wavefront deformation is very low at 4 mλ. The distortion of all field points in the region is below 1 nm. A projection objective is thus created which operates at an operating wavelength of 193 nm, can be produced with the aid of conventional techniques for lens production and coating, and permits a resolution of structures substantially below 100 nm.

The design described is fundamentally suitable for near-field lithography, as well, by the use of a homogeneous immersion. For this purpose, the terminating plano-convex lens 35 is to be combined with the immersion layer 10 to form a lens which can consist, for example, of synthetic quartz glass. In order to permit sufficient light energy of the evanescent field to be coupled in, in this case the working distance between the exit surface of the projection objective and the image plane should be in the region of 100 nm or below.

The specification of the design is summarized in a known way in tabular form in Table 1. Here, column 1 gives the number of a refracting surface, or one distinguished in another way, column 2 gives the radius r of the surface (in mm), column 3 gives the distance d denoted as thickness, of the surface from the following surface (in mm), column 4 gives the material of the optical components, and column 5 gives the refractive

index of the material of the component, which follows the entry surface. The useful, free radii or half the free diameter of the lenses (in mm) are specified in column 6.

In the case of the embodiment, six of the surfaces, specifically the surfaces 4, 6, 15, 29, 34 and 44, are aspheric. Table 2 specifies the corresponding aspheric data, the aspheric surfaces being calculated using the following rule:

$$p(h)=[((1/r)h^2)/(1+SQRT(1-(1+K)(1/r)^2h^2))]+C1*h^4+C2*h^6+\ldots$$

Here, the reciprocal (1/r) of the radius specifies the surface curvature, and h the distance of a surface point from the optical axis. Consequently, p(h) gives the so-called sagitta, that is to say the distance of the surface point from the surface apex in the z direction, that is to say in the direction of the optical axis. The constants K, C1, C2, ... are reproduced in Table 2.

The optical system 1, which can be reproduced with the aid of these data, is designed for an operating wavelength of approximately 193 nm, for which the synthetic quartz glass used for all the lenses has a refractive index n = 1.56029. The image-side numerical aperture is 1.1. The system is adapted to a refractive index of the immersion medium 10 of n = 1.56, which permits a virtually ideal coupling of the light into the immersion layer 10. The objective has an overall length (distance between image plane and object plane) of 1162 mm. A light conductance (product of numerical aperture and image size, also denoted étendue or geometrical flux) of 24.1 mm is achieved given an image size of 22 mm.

A variant of the projection objective shown in Figure 1 is explained with the aid of Figure 2. Lenses or lens groups of the same type or the same

function are denoted by the same reference symbols for reasons of clarity. The system 1' is optimized for a refractive index of the immersion medium of n = 1.37, and this corresponds to a value, which has become known from the literature, of 157 nm for the refractive index of an immersion fluid based on perfluoropolyether (PFPE).

The fourth and the fifth lens group differ in terms of design from that in accordance with Figure 1. In LG4, the thick meniscus lens 28 of the first doublet in Figure 1 is split up into an object-side, biconcave negative lens 28' with an only slightly curved exit side and a subsequent biconvex positive lens 28" with a correspondingly only slightly curved entry side. This splitting-up further reduces the areal stress of the optical surfaces in this region. The rim ray of the projection runs in a converging fashion in the air space between the subsequent lenses 29, 30 upstream of the entry surface of the meniscus 30 which is concave towards the object. In the fifth lens group LG5, the entry-side lenses 31, 32, separated in the case of the design in Figure 1 and downstream of the system aperture 5 are combined to form a single, biconvex positive lens 32'. This is situated at a distance downstream of the system aperture 5, which can be accessed particularly easily. A further special feature consists in that the system aperture 5 is situated between a plane, near the image, of maximum beam diameter and the image plane 3, that is to say where the transilluminated diameter of the lenses already decreases towards the image plane. The other lenses correspond with regard to the type and sequence of the lenses of identical reference symbols in Figure 1. In the case of this design, as well, all the lenses consist of synthetic quartz glass. The specification of this design in the notation described is specified in Tables 3 and 4.

Shown in Figure 3 is a third embodiment, designed for an operating wavelength of 157 nm, of a projection objective 1" whose specification is given in Tables 5 and 6. It is to be seen from the sequence and the type

of lenses that the design is based on the design principle explained with the aid of Figures 1 and 2, and so the same reference symbols are used for lenses and lens groups with corresponding functions. As in the case of the embodiment in accordance with Figure 1, no further optical element is arranged upstream of the first biconcave negative lenses 11 of the objective. As in the case of the embodiment in accordance with Figure 2, in the fourth lens group LG4 the thick meniscus lens 28, still in one piece in Figure 1, is split up into a biconcave negative lens 28' and a directly following biconvex positive lens 28". Just as in the case of the embodiment in accordance with Figure 2, the function of the entry-side lenses 31, 32 of the embodiment in accordance with Figure 1 is taken over by a single, biconvex positive lens 32' which initiates the ray combination towards the image plane. In a way similar to the case of the embodiment in accordance with Figure 2, the system aperture 5 is situated inside the second belly 8 downstream of the region of maximum beam diameter, that is to say where the beam diameter already decreases again towards the image plane.

The refractive index for the immersion medium is set at n = 1.37, which corresponds to a value, which has become known from the literature, for a PFPE-based immersion fluid sufficiently transparent at 157 nm. The image-side working distance is set to approximately 50 μm, which corresponds in practical use to the thickness of the immersion layer. It may be assumed that suitable immersion fluids still have high transmission values of more than 90% in the case of this low thickness, and so only negligible, low transmission losses occur in the region of the immersion, this being favourable for achieving a satisfactory wafer throughput. Pattern widths of less than 70 nm can be resolved with the aid of this purely refractive projection objective, of excellent correction state, which can be implemented using conventional means.

Tables 7 and 8 show the specification of an embodiment (not illustrated pictorially) of a projection objective which is derived from the embodiment in accordance with Figure 3, from which it differs essentially in that the thick meniscus lens 17, concave towards the object, there is replaced by a thinner meniscus lens curved in the same direction. A comparison of Tables 5 and 6 shows that as a result an even more compact design is possible which has smaller lens diameters and a smaller overall length in conjunction with equally good optical properties.

A fourth embodiment of a projection objective 1''', which is designed for an operating wavelength of 193 nm and whose specification is given in Tables 9 and 10 is shown in Figure 4. This embodiment has a projection scale of 4:1 and an image-side numerical aperture NA = 0.9. A comparison with the remaining embodiments shows that less lens material is required in conjunction with the same fundamental optical principle. Instead of 25, as in the case of the other embodiments, there is a need for only 23 lenses, and moreover the average and maximum lens diameters are smaller than with the preceding embodiments. In particular, there is provision in the second lens group LG2 for only three menisci 14, 15, 16, concave towards the object, a lens corresponding to the menisci 17 of the other embodiments being absent. In contrast to the other embodiments, in the fourth lens group LG4 only one doublet 27 and 28 is provided, and so a saving of one lens is made in this lens group as well. The symmetrical design of the third lens group LG3 and of the lens pairs bordering thereon, 19, 20, of the second lens group and 25, 26 of the fourth lens group corresponds to that of the other embodiments. The embodiment in accordance with Figure 4 substantiates that it is also possible to implement solutions of favourable design within the scope of the invention for relatively large projection scales and relatively large fields.

The correction state of all the embodiments shown is excellent. All aberrations are corrected. The maximum RMS value of the wavefront deformation is very low and is below 4.5 mλ for the embodiments in accordance with Figures 1 and 2, below 6.5 mλ for the embodiment in accordance with Tables 7 and 8, and below 5.2 mλ for the embodiment in accordance with Figure 4. Within all the systems, the distortion is in the region below 1 nm for all field points.

It can be seen by the person skilled in the art from the examples that numerous modifications of the designs are possible within the scope of the invention. For example, individual lenses can be split up into two or more separate lenses, or separate lenses can be combined to form a single lens having essentially the same function.

Embodiments with two or more lens materials are also possible. For example, in the case of embodiments for 193 nm it is possible to provide a combination of lenses made from synthetic quartz glass and calcium fluoride in order to facilitate chromatic correction and in order to avoid changes in refractive index because of compaction in regions of high radiation energy densities by using calcium fluoride lenses. Also possible is the use of other materials transparent to the ultraviolet light used, such as barium fluoride, sodium fluoride, lithium fluoride, strontium fluoride, magnesium fluoride or the like.

Catadioptric systems for immersion lithography can also be designed using essential configuration features of the embodiments represented here, in particular in the region, near the image, of the second belly and the aperture stop.

The technical teaching of the invention explained with the aid of various exemplary embodiments shows that a range of design boundary

conditions should be taken into account when the aim is to design an optical system suitable for immersion lithography, particularly one of such compact design. The following features can be beneficial individually or in combination. Immersion objectives for which the image field diameter is greater than approximately 1%, in particular greater than approximately 1.5% of the overall length are favourable. Favourable light conductances (product of image field diameter and numerical aperture) are in the region of above 1%, in particular above 2% of the overall length. Four or more collecting lenses between aperture stop and image plane are favourable, it being preferred for only collecting lenses to be provided in this region. Preferably more than four, five or six consecutive collecting lenses are favourable in the second lens group. In this case, preferably two or more collecting menisci with an object-side concave surface are favourable in the entry region of the second lens group, and two or more collecting menisci with surfaces concave towards the image are favourable at the end of the second lens group. In the region of the first belly or of the second lens group a strong beam expansion is beneficial for which the maximum beam diameter is preferably more than 1.8 times, in particular more than 2 times the object field diameter. The maximum lens diameter in the second lens group can be approximately twice the minimum free lens diameter of the third lens group in the region of the constriction. The maximum lens diameter in the second belly following the constriction is preferably of the same order of magnitude and can, in particular, be greater than twice the minimum free diameter in the third lens group. In the region of the third lens group, that is to say in the region of the waist of the system, two concave surfaces are preferably directly opposite one another and are enclosed by two surfaces curved in the same sense. The lenses respectively adjoining towards the object and towards the image are also preferably designed and arranged in this way.

Particular lens distributions can be favourable. In particular, it is favourable when substantially more lenses are situated upstream of the system aperture than downstream of the aperture. The number of lenses upstream of the aperture is preferably at least four times, in particular more than five times, the number of lenses downstream of the system aperture. Five or more collecting lenses are preferably arranged between the region of narrowest constriction and the system aperture or aperture stop; the axial distance between the region of narrowest constriction and the aperture stop arranged exceptionally near the image is favourably at least 26%, if appropriate more than 30% or 35%, of the overall length of the projection objectives.

Further special features relate to the trajectory of and the relationships between principal rays and rim rays of the projection. Denoted here as principal ray is a ray which runs from a rim point of the object field parallel or at an acute angle to the optical axis and which cuts the optical axis in the region of the system aperture. A rim ray in the sense of the present application leads from the middle of the object field to the rim of the aperture stop. The perpendicular distance of these rays from the optical axis yields the corresponding ray height. It can be favourable when the principle ray height is greater in absolute value up to the end of the second lens group than the rim ray height, this relationship preferably not being reversed until in the region of the third lens group. The maximum rim ray height is preferably more than twice, in particular more than 2.3 to 2.5 times, the rim ray height in the region of the narrowest constriction of the third lens group. It is favourable when the diameter of the rim ray is kept small in the region between the fourth and fifth lens groups, that is to say in the region of the system aperture. This corresponds to a smallest possible focal length of the fifth lens group, following the system aperture. The focal length of the fifth lens group is preferably smaller than 15%, in particular smaller than 10% of the overall length. Preferred systems are doubly telecentric, and so the principal ray

is substantially perpendicular both to the object plane and to the image plane. In preferred systems, the principal ray coming from the object field should still have a divergent trajectory after at least five lenses, that is to say a trajectory with a still rising principal ray height away from the optical axis. It is favourable, furthermore, when the sine of the maximum principal ray divergence angle in the objective region near the object is more than 50% of the object-side numerical aperture. A plurality of aspheric surfaces are preferably provided in the region near the object in which the rim ray height is greater than the principal ray height, in order to promote a favourable correction state.

The invention also relates to a projection exposure machine for microlithography which is distinguished in that it includes a refractive projection objective in accordance with the invention. The projection exposure machine preferably also has devices intended for introducing and keeping an immersion medium, for example a liquid of suitable refractive index, between the last optical surface of the projection objective and the substrate to be exposed. Also covered is a method for producing semiconductor components and other finely structured structural elements, in the case of which an image of a pattern arranged in the object plane of a projection objective is projected in the region of the image plane, an immersion medium arranged between the projection objective and the substrate to be exposed and transparent to light at the operating wavelength being transilluminated.

Table 1

SURFACE	RADII	THICKNESSES	LENSES	REFRACTIVE INDEX 193.304 nm	1/2 FREE DIAMETER
0	0.000000000	21.980160000			55.000
1	0.000000000	5.569665462			59.973
2	-697.373131352	6.830738819	SIO2	1.56028900	60.658
3	317.877790816	13.366856184			63.806
4	-389.517361474AS	8.019967568	SIO2	1.56028900	65.103
5	684.978717634	23.693566944			70.051
6	612.579041806AS	13.565039007	SIO2	1.56028900	66.338
7	315.238108546	24.050777166			92.585
8	-636.903175512	64.776662854	SIO2	1.56026900	95.153
9	-304.036729565	1.000000000			120.585
10	-942.407223581	39.153776761	SIO2	1.56028500	130.798
11	-317.623154272	1.312033169			137.817
12	-856.579360710	53.698176363	SIO2	1.56028500	145.587
13	-222.120764338	1.000000000			148.413
14	-365.979641333	16.565547178	SIO2	1.56028900	148.696
15	-300.375347712	1.000000000			150.000
16	622.472470310	44.791302453	SIO2	1.56028900	146.389
17	-556.306013695	1.020913522			145.384
18	135.290972565	40.672419816	SIO2	1.56026900	113.552
19	140.228400611	1.007703555			99.382
20	128.146489274	33.605830320	SIO2	1.56028900	97.047
21	178.381821741	21.367336106			87.913
22	764.210626300	8.040530767	SIO2	1.56028900	85.346
23	81.619567541	55.132180427			66.098
24	-324.577506735	8.010204876	SIO2	1.56028900	63.499
25	133.065440504AS	29.116630876			62.507
26	-275.984572757	12.121405585	SIO2	1.56026900	63.961
27	2685.503343355	41.843073620			68.171
28	-83.024363434	9.316662930	SIO2	1.56028900	69.398
29	-271.500870518AS	7.122879020			90.369
30	-234.062816820	34.813633391	SIO2	1.56028900	93.111
31	-128.679213398	1.375380851			98.648
32	-371.070689222	40.964768288	SIO2	1.56026900	112.720
33	-158.555144143	2.142646331			116.033
34	844.565103125AS	42.656894678	SIO2	1.56026900	123.022
35	-293.770426726	28.164927093			123.344
36	-170.081620687	40.277028630	SIO2	1.56028900	122.713
37	-316.315520485	10.983607028			137.139
38	623.625571533	56.798798505	SIO2	1.56028900	143.361
39	-379.372716473	20.156323351			143.139
40	-246.931005408	18.587257168	SIO2	1.56028900	142.262
41	-460.148730828	16.465394474			145.978
42	0.000000000	-15.465394474			144.329
43	506.946830874	18.875460558	SIO2	1.56028900	144.915
44	1011.956468931AS	22.930981004			144.124
45	1760.701259607	42.739861527	SIO2	1.56028900	143.914
46	-371.926449461	1.361397272			143.620
47	194.244261542	42.532993341	SIO2	1.56028900	120.019
48	689.962205932	1.126753967			114.927
49	109.590774593	34.370356865	SIO2	1.56028900	88.972
50	156.823775540	1.072372528			79.549
51	118.692607648	80.000000000	SIO2	1.56028900	73.749
52	0.000000000	8.436241391	Immersion	1.56000000	19.439
53	0.000000000	0.000000000			11.000

Table 2

ASPHERIC CONSTANTS

SURFACE NO. 4

K	0.0000
C1	2.13047921e-007
C2	-3.57933301e-011
C3	2.93263063e-015
C4	-4.61461071e-019
C5	2.76861570e-023
C6	1.62740830e-027
C7	-3.43732853e-031
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 6

K	0.0000
C1	-1.14265623e-007
C2	2.02166625e-011
C3	-1.76403105e-015
C4	2.36305340e-019
C5	-2.55314839e-023
C6	1.35459868e-027
C7	-2.70730236e-032
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 25

K	0.0000
C1	-9.78914413e-008
C2	-4.33168283e-012
C3	-8.01001563e-017
C4	-1.31611936e-019
C5	6.54375176e-023
C6	-1.37293557e-026
C7	1.58764578e-030
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 29

K	0.0000
C1	2.99497807e-008
C2	-3.16131943e-012
C3	-9.61008384e-017
C4	2.05647555e-020
C5	-2.56167018e-024
C6	1.74321022e-028
C7	-7.59802684e-033
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 34

K	0.0000
C1	-5.83593306e-009
C2	-4.08253893e-015
C3	-3.40928951e-018
C4	1.36466423e-022
C5	-1.03090955e-026
C6	4.02018916e-031
C7	-9.89542799e-036
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 44

K	0.0000
C1	-5.18910040e-009
C2	3.51025484e-013
C3	-5.47716488e-018
C4	4.43561455e-023
C5	3.42844064e-028
C6	-1.97724021e-032
C7	2.22456117e-037
C8	0.00000000e+000
C9	0.00000000e+000

Table 3

SURFACE	RADII	THICKNESSES	LENSES	REFRACTIVE INDEX ???.?? nm	1/2 FREE DIAMETER
0	0.000000000	21.980160000	L710	0.99998200	55.000
1	0.000000000	6.228362492	L710	0.99998200	59.974
2	-603.070624671	9.913063455	SIO2HL	1.56028900	60.690
3	280.916333783	13.300217883	HE193	0.99971200	64.385
4	-461.660931347AS	8.000000000	SIO2HL	1.56028900	65.798
5	681.261406487	25.180533824	HE193	0.99971200	70.487
6	421.796712825AS	13.410028997	SIO2HL	1.56028900	89.920
7	306.236502978	23.641854301	HE193	0.99971200	95.293
8	-881.743075986	64.144962259	SIO2HL	1.56028900	97.777
9	-397.616228767	1.032715830	HE193	0.99971200	123.195
10	-1049.995266570	39.473283137	SIO2HL	1.56028900	130.947
11	-266.549348161	2.251083976	HE193	0.99971200	136.447
12	-659.273684770	52.089256568	SIO2HL	1.56028900	143.894
13	-209.207390137	1.008491553	HE193	0.99971200	146.415
14	-565.795559961	15.829681399	SIO2HL	1.56028900	145.408
15	-410.848668817	1.000000613	HE193	0.99971200	146.045
16	809,207497255	37.599045382	SIO2HL	1.56028900	142.424
17	-599.260287529AS	1.000000015	HE193	0.99971200	141.453
18	136.304287826	42.528385200	SIO2HL	1.56028900	113.454
19	157.516637917	1.000000000	HE193	0.99971200	101.084
20	126.013978931	34.051407776	SIO2HL	1.56028900	96,007
21	157.519818686	23.554259229	HE193	0.99971200	84.914
22	795.455608357	9.035828932	SIO2HL	1.56028900	82.369
23	78.918295716	38.235934318	HE193	0.99971200	63.551
24	-647.136797738	8.000000184	SIO2HL	1.56028900	63.056
25	148.158813477AS	22.440106724	HE193	0.99971200	61.484
26	-197.858636028	9.960377452	SIO2HL	1.56028900	62.472
27	1367.448704100	41.007582498	HE193	0.99971200	66.716
28	-87.255013445	8.475217865	SIO2HL	1.56028900	68.713
29	-396.760639119AS	6.473661900	HE193	0.99971200	80.202
30	-317.095597644	34.300021646	SIO2HL	1.56028900	90.935
31	-136.816156215	1.956487291	HE193	0.99971200	96.054
32	-384.621022314	38.250891268	SIO2HL	1.56028900	107.862
33	-158.063116797	1.000000006	HE193	0.99971200	111.057
34	807.690134076AS	41.496271568	SIO2HL	1.56028900	117.589
35	-280.885163902	25.354810908	HE193	0.99971200	117.901
36	-166.502630134	9.238823967	SIO2HL	1.56028900	117.263
37	988.468038668	6.603211723	HE193	0.99971200	131.802
38	1106.583200370	44.085572378	SIO2HL	1.56028900	134.587
39	-353.437766566	1.000000005	HE193	0.99971200	136.483
40	445.824457242	52.624318854	SIO2HL	1.56028900	142.739
41	-460.556866224AS	26.188809880	HE193	0.99971200	142.372
42	-248.318425801	36.706472160	SIO2HL	1.56028900	141.622
43	-340.049722714AS	16.312593082	HE193	0.99971200	146.673
44	0.000000000	12.926710616	HE193	0.99971200	142.237
45	1036.963505660	42.907368082	SIO2HL	1.56028900	142.523
46	-417.465602619	1.875432853	HE193	0.99971200	142.184
47	189.031074062	41.889218814	SIO2HL	1.56028900	121.251
48	698.095904580AS	1.076370948	HE193	0.99971200	117.434
49	109.988479121	34.053123871	SIO2HL	1.56028900	91.356
50	167.347263939	1 034746212	HE193	0.99971200	84.177
51	123.915863411	79 999373259	SIO2HL	1.56028900	77.713
52	0.000000000	10 366030727	IMMERS	1.37000000	25.089
53	0.000000000	0.000000000		1.00000000.	11.000

Table 4

ASPHERIC CONSTANTS

SURFACE NO. 4

K	0.0000
C1	2.26522214e-007
C2	-3.59236651e-011
C3	2.92133725e-015
C4	-3.77696224e-019
C5	7.96388858e-024
C6	3.51986385e-027
C7	-4.54711324e-031
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 6

K	0.0000
C1	-1.19063117e-007
C2	1.94138266e-011
C3	-1.81962009e-015
C4	2.25193097e-019
C5	-2.25566558e-023
C6	1.19237134e-027
C7	-2.51584924e-032
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 17

K	0.0000
C1	1.74375723e-011
C2	-2.04139734e-014
C3	7.67666306e-019
C4	-1.93715606e-023
C5	1.92834024e-027
C6	-7.02565837e-032
C7	1.14576119e-036
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 25

K	0.0000
C1	-6.99705361e-008
C2	-3.25537639e-012
C3	-2.93013408e-016
C4	-9.17751598e-020
C5	4.34261555e-023
C6	-1.01901896e-026
C7	1.42841266e-030
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 29

K	0.0000
C1	3.01668174e-008
C2	-4.16186211e-012
C3	-2.10017649e-017
C4	1.39690646e-020
C5	-1.51163159e-024
C6	6.56920089e-029
C7	-3.15414270e-033
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 34

K	0.0000
C1	-4.23637017e-009
C2	-3.29710303e-014
C3	-3.52756803e-018
C4	-4.13266120e-023
C5	-2.18653880e-027
C6	2.27691141e-031
C7	-8.70596013e-036
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 41

K	0.0000
C1	3.45855942e-009
C2	5.47566277e-014
C3	-3.85610770e-018
C4	2.74041138e-023
C5	1.86632362e-027
C6	-3.44742394e-032
C7	3.29571792e-038
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 43

K	0.0000
C1	-3.55873802e-010
C2	9.63322458e-014
C3	-7.64415866e-019
C4	2.00153471e-023
C5	-1.98329358e-027
C6	5.52524526e-032
C7	-4.80876507e-037
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 48

K	0.0000
C1	-2.25289484e-009
C2	2.62711822e-013
C3	3.12883195e-018
C4	-2.96009757e-022
C5	1.93969203e-026
C6	-7.02702044e-031
C7	1.40339412e-035
C8	0.00000000e+000
C9	0.00000000e+000

Table 5

SURFACE	RADII	THICKNESSES	LENSES	REFRACTIVE INDEX ???.?? nm	1/2 FREE DIAMETER
0	0.000000000	21.580160000	L710	1.00000000	55.000
1	0.000000000	5.521159992	L710	1.00000000	59.973
2	-653.380153342	10.765637537	CAF2HL	1.55848720	60.652
3	234.866815376	14.392447066	HE193	1.00000000	64.672
4	-541.443785623AS	8.065018137	CAF2HL	1.55848720	66.216
5	809.887192810	22.060952617	HE193	1.00000000	70.663
6	437.017712375AS	16.925405940	CAF2HL	1.55848720	88.269
7	315.047933823	22.322216303	HE193	1.00000000	94.661
8	-1055.166104070	68.241607282	CAF2HL	1.55848720	97.341
9	-440.417777767	1.950157109	HE193	1.00000000	124.495
10	-833.235756565	45.202958015	CAF2HL	1.55848720	130.520
11	-248.097167968	6.567867993	HE193	1.00000000	136.785
12	-667.629333065	58.527118374	CAF2HL	1.55848720	147.021
13	-230.265801432	1.000000000	HE193	1.00000000	152.069
14	-635.989091493	52.689533957	CAF2HL	1.55848720	151.782
15	-420.897980530	1.000000000	HE193	1.00000000	155.231
16	682.574050518	42.565469096	CAF2HL	1.55848720	150.819
17	-650.602325928AS	1.000000000	HE193	1.00000000	149.697
18	143.909393739	39.312156678	CAF2HL	1.55848720	117.562
19	170.361039751	1.000000000	HE193	1.00000000	106.663
20	-127.366697165	33.064705940	CAF2HL	1.55848720	99.558
21	149.757517850	27.658696477	HE193	1.00000000	88.267
22	893.404652749	8.000000000	CAF2HL	1.55848720	85.687
23	85.474739309	42.082501866	HE193	1.00000000	67.021
24	-554.412638267	8.000000000	CAF2HL	1.55848720	65.854
25	133.887772525AS	36.097576773	HE193	1.00000000	63.605
26	-202.032636775	8.000000000	CAF2HL	1.55848720	64.919
27	-1368.827225050	39.670298843	HE193	1.00000000	68.993
28	-87.722719327	8.150939605	CAF2HL	1.55848720	70.057
29	-341.867554503AS	7.243142706	HE193	1.00000000	89.680
30	-270.393973331	34.812062471	CAF2HL	1.55848720	92.272
31	-131.925970131	1.000000000	HE193	1.00000000	97.490
32	-356.379287279	37.218470508	CAF2HL	1.55848720	109.741
33	-160.486739217	1.000000000	HE193	1.00000000	113.010
34	728.417353927AS	44.411516365	CAF2HL	1.55848720	121.086
35	-285.991760803	26.777077207	HE193	1.00000000	121.404
36	-169.413078236	8.000000000	CAF2HL	1.55848720	120.698
37	1233.439177430	5.704973599	HE193	1.00000000	135.519
38	1968.954811160	42.925033480	CAF2HL	1.55848720	136.852
39	-334.436426428	1.000000000	HE193	1.00000000	138.799
40	448.482885926	53.515273929	CAF2HL	1.55848720	145.983
41	-481.776223591AS	38.664604302	HE193	1.00000000	145.641
42	-257.207339099	39.651511432	CAF2HL	1.55848720	141.395
43	-352.351244424AS	8.074724759	HE193	1.00000000	146.219
44	0.000000000	8.135112666	HE193	1.00000000	142.806
45	1571.538613070	41.393617207	CAF2HL	1.55848720	143.060
46	-395.530190539	4.955628551	HE193	1.00000000	142.883
47	189.594554041	44.893603417	CAF2HL	1.55848720	122.058
48	737.400220721AS	1.254530428	HE193	1.00000000	117.739
49	113.971025132	34.166140572	CAF2HL	1.55848720	91.979
50	186.560340242	1.000000000	HE193	1.00000000	85.029
51	124.935012572	92.227373544	CAF2HL	1.55848720	76.952
52	0.000000000	0.050000026	IMMERS	1.37000000	11.068
53	0.000000000	0.000000000		1.00000000	11.000

Table 6

ASPHERIC CONSTANTS

SURFACE NO. 4

K	7.3965
C1	2.19490389e-007
C2	-3.18478613e-011
C3	2.65699241e-015
C4	-3.54396715e-019
C5	1.30925174e-023
C6	2.26447806e-027
C7	-2.54478129e-031
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 6

K	0.6253
C1	-1.14294859e-007
C2	1.87842360e-011
C3	-1.79164088e-015
C4	2.34304280e-019
C5	-2.31194495e-023
C6	1.12536497e-027
C7	-2.03074756e-032
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 17

K	0.7878
C1	-3.05430457e-010
C2	-4.89773138e-014
C3	1.06523190e-018
C4	-1.47516954e-023
C5	1.34357246e-027
C6	-5.23906249e-032
C7	8.17069597e-037
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 25

K	0.0013
C1	-6.90163161e-008
C2	-2.08803493e-012
C3	-3.48958289e-016
C4	-3.58451964e-020
C5	2.16254654e-023
C6	-3.96801026e-027
C7	6.60002235e-031
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 29

K	-0.0334
C1	3.02609727e-008
C2	-3.89225347e-012
C3	-2.10302538e-017
C4	1.38850354e-020
C5	-1.75136022e-024
C6	5.45164389e-029
C7	-4.34831621e-033
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 34

K	1.5440
C1	-3.43367330e-009
C2	-1.34450662e-014
C3	-2.29266384e-018
C4	9.75729676e-023
C5	-1.35202712e-026
C6	8.80518329e-031
C7	-2.65068179e-035
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 41

K	0.0872
C1	3.26909609e-009
C2	7.76009100e-014
C3	-3.82550397e-018
C4	2.28007850e-023
C5	-2.34153651e-028
C6	1.34376006e-032
C7	-1.01621932e-036
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 43

K	0.0312
C1	-4.99867832e-010
C2	1.15316140e-013
C3	-1.41640795e-018
C4	7.05365641e-023
C5	-2.43649494e-027
C6	6.83361566e-032
C7	-6.25588420e-037
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 48

K	-1.8716
C1	-4.01414746e-009
C2	1.94301708e-013
C3	4.07775084e-018
C4	-4.70574709e-022
C5	2.42642656e-026
C6	-8.38949812e-031
C7	1.38189311e-035
C8	0.00000000e+000
C9	0.00000000e+000

Table 7

SURFACE	RADII	THICKNESSES	LENSES	REFRACTIVE INDEX 157.6 nm	1/2 FREE DIAMETER
0	0.000000000	21.980160000			55.000
1	0.000000000	5.694922030			59.974
2	-683.677082960	0.000016965	CAF2HL	1.55848720	60.653
3	241.804516194	13.492175419			64.060
4	-561.327374916AS	8.000000000	CAF2HL	1.55848720	65.556
5	699.454774317	23.282413511			69.867
6	400.792577467AS	11.762291230	CAF2HL	1.55848720	88.232
7	293.254615517	22.385108600			92.839
8	-1055.962319550	71.454692862	CAF2HL	1.55848720	95.242
9	-483.111728442	2.387528569			124.181
10	-967.495111648	48.847817148	CAF2HL	1.55848720	130.362
11	-235.896512938	5.659224997			136.444
12	-579.940954244	54.879651202	CAF2HL	1.55848720	145.324
13	-221.637621298	1.000000000			149.602
14	-775.372223325	15.081823940	CAF2HL	1.55848720	147.807
15	-525.919668017	1.000000000			148.157
16	660.302511324	38.720317303	CAF2HL	1.55848720	144.440
17	-732.467945129AS	1.000000000			143.303
18	147.955956945	38.541140120	CAF2HL	1.55848720	116.315
19	174.954421407	1.000000000			105.360
20	118.333525649	33.404122786	CAF2HL	1.55848720	96.491
21	140.216192098	28.013496674			85.972
22	788.027919344	8.457239690	CAF2HL	1.55848720	83.494
23	83.038332631	41.178404325			65.374
24	-597.396381251	8.000000000	CAF2HL	1.55848720	64.284
25	136.956016017AS	31.536496068			62.327
26	-200.199292002	8.000000000	CAF2HL	1.55848720	63.210
27	1650.730497600	43.442178500			66.958
28	-86.362069271	8.210360232	CAF2HL	1.55848720	69.385
29	-360.179451570AS	2.567422592			89.255
30	-280.601605332	34.872981631	CAF2HL	1.55848720	92.027
31	-132.713942595	1.004709559			97.215
32	-361.662148157	37.722697596	CAF2HL	1.55848720	109.325
33	-159.165877620	1.000000000			112.571
34	750.946018427AS	43.541363913	CAF2HL	1.55848720	120.144
35	-265.806553705	25.930047100			120.440
36	-169.581349559	8.030377840	CAF2HL	1.55848720	119.789
37	1077.110465570	5.682989489			134.185
38	1605.653205960	43.332820801	CAF2HL	1.55848720	135.539
39	-333.794563037	1.000000000			137.425
40	448.584289713	52.027765048	CAF2HL	1.55848720	144.043
41	-487.266144069AS	37.362834300			143.681
42	-256.080121302	40.279714930	CAF2HL	1.55848720	139.838
43	-353.759022671AS	7.564240001			144.656
44	0.000000000	10.832272687			141.334
45	1499.148900820	42.690870531	CAF2HL	1.55848720	141.660
46	-394.545474104	2.390581943			141.445
47	188.988731298	43.117430646	CAF2HL	1.55848720	121.630
48	731.593986095AS	1.000000000			117.999
49	114.385993039	33.926813476	CAF2HL	1.55848720	92.421
50	184.018639075	1.000000000			85.485
51	123.357011160	93.333990149	CAF2HL	1.55848720	77.332
52	0.000000000	0.050000000	Immersion	1.37000000	11.068
53	0.000000000	0.000000000			11.000

Table 8

ASPHERIC CONSTANTS

SURFACE NO. 4

K	2.4014
C1	2.24623581e-007
C2	-3.32717029e-011
C3	2.75311747e-015
C4	-3.79340993e-019
C5	1.61861324e-023
C6	2.15579277e-027
C7	-2.81911737e-031
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 6

K	1.5259
C1	-1.12174954e-007
C2	1.85234618e-011
C3	-1.79384980e-015
C4	2.32576675e-019
C5	-2.32368876e-023
C6	1.17478944e-027
C7	-2.27644098e-032
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 17

K	1.0238
C1	-4.04184504e-010
C2	-5.52221230e-014
C3	1.07792813e-018
C4	-9.68577933e-024
C5	1.93184487e-027
C6	-7.97233584e-032
C7	1.33745628e-036
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 25

K	0.0096
C1	-6.72070580e-008
C2	-2.66011173e-012
C3	-4.29366635e-016
C4	-8.52658144e-020
C5	3.61027613e-023
C6	-7.30829628e-027
C7	1.01938199e-030
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 29

K	-0.2769
C1	3.11335863e-008
C2	-4.05777758e-012
C3	-6.25958384e-018
C4	1.47181039e-020
C5	-1.67736576e-024
C6	7.46972419e-029
C7	-2.84782511e-033
C6	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 34

K	1.5943
C1	-3.41875063e-009
C2	-1.06207572e-014
C3	-2.75870187e-018
C4	1.25443795e-022
C5	-1.53842992e-026
C6	9.81335165e-031
C7	-2.88557010e-035
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 41

K	0.1099
C1	3.24105758e-009
C2	7.37348572e-014
C3	-3.58460435e-018
C4	2.55537441e-023
C5	-1.78486202e-028
C6	1.62622698e-032
C7	-1.16103266e-036
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 43

K	0.0331
C1	-4.94661761e-010
C2	1.05503739e-013
C3	-1.45124835e-018
C4	6.84809756e-023
C5	-2.60450711e-027
C6	7.57276741e-032
C7	-7.11474674e-037
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 46

K	-1.6262
C1	-4.00081230e-009
C2	1.92491101e-013
C3	3.74576393e-018
C4	-4.50566284e-022
C5	2.41249474e-026
C6	-8.61661412e-031
C7	1.44171593e-035
C6	0.00000000e+000
C9	0.00000000e+000

Table 8

SURFACE	RADII	THICKNESSES	LENSES	REFRACTIVE INDEX 193.368 nm	1/2 FREE DIAMETER
0	0.000000000	21.980160000		1.00000000	56.080
1	0.000000000	3.246886384	L710	0.99998200	61.197
2	-7758.872975441	8.000000000	SIO2HL	1.56028900	61.896
3	355.789182967	7.529172915	HE193	0.99971200	63.992
4	1890.369849232AS	8.000000000	SIO2HL	1.56028900	65.078
5	268.213281606	15.157771412	HE193	0.99971200	68.460
6	3183.174654849AS	8.000000000	SIO2HL	1.56028900	72.301
7	542.737427921	25.228019508	HE193	0.99971200	76.281
8	-190.186659474	54.303344531	SIO2HL	1.56028900	78.244
9	-200.972554549	1.000000000	HE193	0.99971200	102.934
10	-1181.739114120	41.618091168	SIO2HL	1.56028900	116.315
11	-200.599785289	1.000000000	HE193	0.99971200	119.335
12	-345.801617038	34.756009233	SIO2HL	1.56028900	122.895
13	-183.035949027	1.000000000	HE193	0.99971200	125.001
14	468.598304219	28.888366130	SIO2HL	1.56028900	119.583
15	-1579.330378954AS	1.000000000	HE193	0.99971200	118.410
16	130.622577421	25.607493426	SIO2HL	1.56028900	101.535
17	167.663753864	1.000000000	HE193	0.99971200	96.903
18	109.515012627	33.485629573	SIO2HL	1.56028900	88.871
19	139.697752059	27.284753341	HE193	0.99971200	79.284
20	8434.054206242	8.000000000	SIO2HL	1.56028900	76.872
21	75.280373304	30.508120723	HE193	0.99971200	60.167
22	712.917049547	8.000000000	SIO2HL	1.56028900	59.980
23	137.047950349AS	41.376149328	HE193	0.99971200	58.756
24	-120.268111858	8.000000000	SIO2HL	1.56028900	60.070
25	-335.689995101	26.955101014	HE193	0.99971200	64.725
26	-86.294324443	8.405631441	SIO2HL	1.56028900	65.622
27	-401.221976575AS	6.791819241	HE193	0.99971200	82.386
28	-295.528316934	33.017957091	SIO2HL	1.56028900	84.761
29	-156.211920694	1.000000000	HE193	0.99971200	93.276
30	-268.979127216	33.049041389	SIO2HL	1.56028900	99.716
31	-143.116315961	1.000000000	HE193	0.99971200	103.445
32	472.893961029AS	41.687451272	SIO2HL	1.56028900	115.709
33	-346.217421041	22.889302349	HE193	0.99971200	116.094
34	-187.601096847	12.645469238	SIO2HL	1.56028900	115.710
35	-359.852656461	1.000000000	HE193	0.99971200	121.777
36	722.017664882	60.459509481	SIO2HL	1.56028900	125.218
37	-1816.432711581AS	24.260456335	HE193	0.99971200	125.322
38	2199.280274610	24.178147653	SIO2HL	1.56028900	124.815
39	-1512.556721835	8.000000000	HE193	0.99971200	124.440
40	0.000000000	14.309578556	HE193	0.99971200	123.088
41	1738.196399601	35.559449287	SIO2HL	1.56028900	124.310
42	-429.627570104AS	1.000000000	HE193	0.99971200	124.575
43	179.589102742	55.687793359	SIO2HL	1.56028900	115.507
44	589.027987743AS	10.530033379	HE193	0.99971200	105.186
45	136.621156961	53.097791469	SIO2HL	1.56028900	89.320
46	137.713821680	1.000000000	HE193	0.99971200	67.001
47	93.326477153	90.505495277	SIO2HL	1.56028900	62.339
48	0.000000000	1.000000545	IMMERS	1.56000000	14.735
49	0.000000000	0.000000000		1.00000000	14.020

Table 10

ASPHERIC CONSTANTS

SURFACE NO. 4

K	0.0000
C1	2.81531001e-007
C2	-3.99703415e-011
C3	2.76850090e-015
C4	-4.54887122e-019
C5	-5.66904777e-024
C6	5.03662466e-027
C7	-4.52060360e-031
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 6

K	0.0000
C1	-1.16706261e-007
C2	2.00348321e-011
C3	-1.51130378e-015
C4	3.05660955e-019
C5	-1.76658953e-023
C6	3.15835636e-027
C7	-4.23595936e-031
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 15

K	0.0000
C1	-9.37524970e-010
C2	-2.58161066e-013
C3	-5.12306559e-018
C4	1.80598481e-022
C5	3.60539800e-027
C6	3.85878819e-031
C7	-3.50550744e-037
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 23

K	0.0000
C1	-9.05676602e-008
C2	-7.64727914e-013
C3	-9.31867049e-016
C4	9.20035750e-020
C5	-9.15433014e-023
C6	1.32736186e-026
C7	-9.23872382e-031
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 27

K	0.0000
C1	2.51519254e-006
C2	-4.37829106e-012
C3	2.66987306e-017
C4	1.45024261e-020
C5	-1.31152094e-024
C6	1.04657156e-030
C7	-5.21174949e-034
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 32

K	0.0000
C1	-2.59168418e-009
C2	-8.93760219e-014
C3	-4.25486946e-018
C4	3.13097668e-022
C5	-1.87333640e-026
C6	1.28572875e-030
C7	-3.94471730e-035
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 37

K	0.0000
C1	3.92265908e-009
C2	5.90432031e-014
C3	-4.61273256e-018
C4	5.09437288e-023

Patent Claims

1. Refractive projection objective for projecting a pattern arranged in an object plane of the projection objective into an image plane of the projection objective with the aid of an immersion medium which is arranged between a last optical element of the projection objective and the image plane, comprising:
a first lens group (LG1), following the image plane, with a negative refracting power;
a second lens group (LG2), following the first lens group, with a positive refracting power;
a third lens group (LG3), following the second lens group, with a negative refracting power;
a fourth lens group (LG4), following the third lens group, with a positive refracting power;
a fifth lens group (LG5), following the fourth lens group, with a positive refracting power; and
a system aperture (5) which is arranged in the region of maximum beam diameter between the fourth and the fifth lens group.

2. Projection objective according to Claim 1, wherein the system aperture (5) lies between a plane of maximum beam diameter near the image and the image plane (3).

3. Projection objective according to Claim 1 or 2 which has an image-side numerical aperture NA $\geq$ 0.9, the image-side numerical aperture preferably being at least NA = 1.0.

4. Projection objective according to one of the preceding claims, wherein the projection objective is adapted to an immersion medium (10) which has a refractive index of n > 1.3 at the operating wavelength.

5. Projection objective according to one of the preceding claims, wherein the projection objective has an image-side working distance of between approximately 10 μm and approximately 200 μm, in particular between approximately 20 μm and approximately 100 μm.

6. Projection objective according to one of the preceding claims, wherein a ratio between the focal length of the fourth lens group (LG4) and the focal length of the fifth lens group (LG5) is between approximately 0.9 and approximately 1.1.

7. Projection objective according to one of the preceding claims, wherein a ratio of the magnitudes of the focal lengths of the first lens group (LG1) and the fifth lens group (LG5) is between approximately 0.7 and approximately 1.3, in particular between approximately 0.9 and approximately 1.1.

8. Projection objective according to one of the preceding claims, wherein a ratio between the overall length of the projection objective and the focal length of the fifth lens group (LG5) is greater than five, preferably greater than six, in particular greater than eight.

9. Projection objective according to one of the preceding claims, wherein the first lens group (LG1) includes at least one aspheric surface, two aspheric surfaces preferably being provided in the first lens group.

10. Projection objective according to one of the preceding claims, wherein at least one aspheric surface is provided in the third lens group (LG3), two aspheric surfaces preferably being provided.

11. Projection objective according to one of the preceding claims, wherein at least one aspheric surface is arranged in the first lens group,

and/or wherein not more than nine aspheric surfaces are provided, less than seven aspheric surfaces preferably being provided.

12. Projection objective according to one of the preceding claims, wherein at least one meniscus lens (13), convex relative to the object plane, with a negative refracting power is arranged in the near zone of the object plane (2), in particular inside the first lens group (LG1).

13. Projection objective according to one of the preceding claims, wherein the second lens group has at least four, preferably at least five or six consecutive lenses (14 to 20) with a positive refracting power.

14. Projection objective according to one of the preceding claims, wherein the second lens group (LG2) has at least one, preferably a plurality of meniscus lenses (14, 15, 16, 17), concave relative to the object plane, with a positive refracting power on an entry side facing the object plane (2), and/or wherein the second lens group has at least one, preferably a plurality of meniscus lenses (19, 20), convex relative to the object plane, with a positive refracting power on the exit side facing the image plane.

15. Projection objective according to one of the preceding claims, wherein the second lens group (LG2) in this sequence has at least one meniscus lens (14, 15, 16, 17), concave relative to the object plane, with a positive refracting power, a biconvex positive lens (18) and at least one meniscus lens (19, 20), concave relative to the image plane, with a positive refracting power.

16. Projection objective according to one of the preceding claims, wherein the third lens group (LG3) has only lenses (21, 22, 23, 24) with a negative refracting power.

17. Projection objective according to one of the preceding claims, wherein, with reference to a plane (9) of symmetry lying inside the third lens group (LG3), the third lens group is of substantially symmetrical construction, and/or wherein two oppositely curved, concave surfaces directly opposed to one another in the third lens group (LG3) and are surrounded by two concave surfaces which are concave relative to one another.

18. Projection objective according to one of the preceding claims, wherein an exit region, facing the third lens group (LG3), of the second lens group (LG2), and an entry region, following the third lens group, of the fourth lens group (LG4) are constructed substantially symmetrically relative to a plane (9) of symmetry lying inside the third lens group.

19. Projection objective according to one of the preceding claims, wherein the fourth lens group (LG4) has at least one doublet (27, 28, 29, 30) with a biconvex positive lens (27, 29) and a downstream negative meniscus lens (28, 30) with lens surfaces which are concave towards the object, at least two doublets preferably being provided.

20. Projection objective according to one of the preceding claims, wherein in an object-side entry region the fourth lens group (LG4) has at least one meniscus lens (25, 26), concave relative to the object plane (2), with a positive refracting power, a plurality of such meniscus lenses preferably being provided consecutively.

21. Projection objective according to one of the preceding claims, wherein the sine of the maximum incidence angle of the radiation impinging on the optical surfaces is less than 90%, in particular less than 85% of the image-side numerical aperture.

22. Projection objective according to one of the preceding claims, wherein the fifth lens group (LG5) has exclusively lenses with a positive refracting power.

23. Projection objective according to one of the preceding claims, wherein the fifth lens group has at least four positive lenses (31 to 35).

24. Projection objective according to one of the preceding claims, wherein the fifth lens group (LG5) has at least one meniscus lens (33, 34) with a positive refracting power and lens surfaces concave towards the image.

25. Projection objective according to one of the preceding claims, wherein as last optical element the fifth lens group (LG5) has a plano-convex lens (35) which preferably has a spherical entry surface and a substantially flat exit surface.

26. Projection objective according to Claim 25, wherein the plano-convex lens (35) is constructed in a nonhemispherical fashion.

27. Projection objective according to one of the preceding claims, wherein all the lenses consist of the same material, use preferably being made of synthetic quartz glass as lens material for a 193 nm operating wavelength, and/or of calcium fluoride as lens material for a 157 nm wavelength.

28. Projection objective according to one of the preceding claims which is a single-waist system with a belly (6) near the object, a belly (8) remote from the object and a waist (7) therebetween.

29. Projection objective according to one of the preceding claims, wherein the image field diameter is more than 10 mm, in particular more

than 20 mm and/or wherein the image field diameter is more than 1.0%, in particular more than 1.5%, of the overall length.

30. Projection objective according to one of the preceding claims, wherein the light conductance is more than approximately 1%, in particular more than approximately 2% of the overall length.

31. Projection objective according to one of the preceding claims, wherein substantially more lenses are arranged upstream of the system aperture (5) than downstream of the system aperture, preferably at least four times as many.

32. Projection objective according to one of the preceding claims, wherein at least five lenses with a positive refracting power are arranged between the waist and the system aperture (5).

33. Projection objective according to one of the preceding claims, wherein a distance between the waist and the system aperture is at least 26% of the overall length, preferably more than 30% of the overall length.

34. Projection objective according to one of the preceding claims, wherein a maximum rim ray height is at least twice as large as the rim ray height at the location of the narrowest constriction.

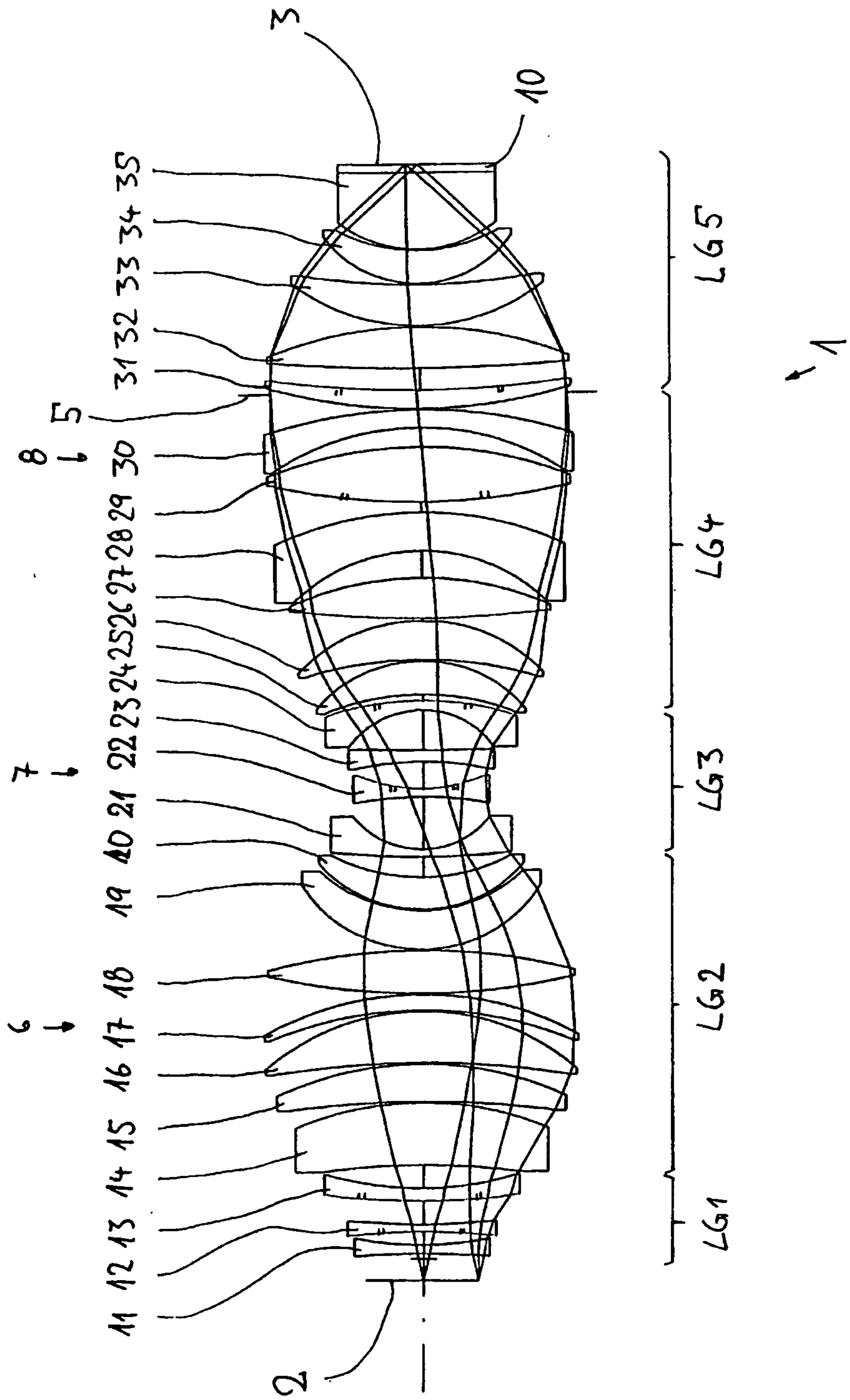
35. Projection exposure machine for microlithography, characterized by a refractive projection objective (1, 1', 1") in accordance with one of the preceding claims.

36. Method for producing semiconductor components and other finely structured structural elements, having the following steps:
providing a mask with a prescribed pattern;

illuminating the mask with ultraviolet light of a prescribed wavelength; and

projecting an image of the pattern onto a photosensitive substrate, arranged in the region of the image plane of a projection objective, with the aid of a projection objective in accordance with one of the preceding Claims 1 to 34;

an immersion medium arranged between a last optical surface of the projection objective and the substrate being transilluminated during the projection.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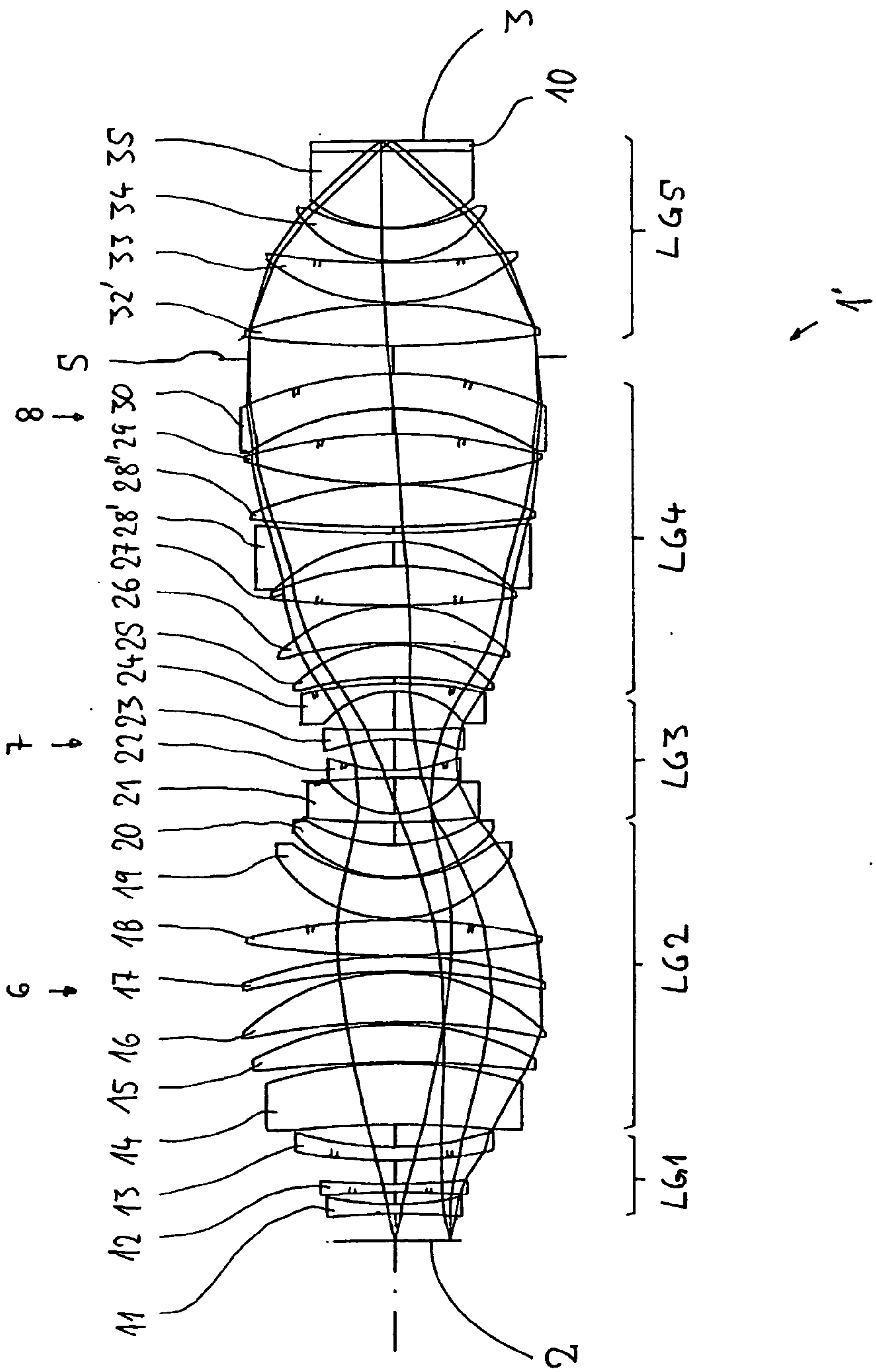
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
LG1
LG2
LG3
LG4
LG5

Fig. 1



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LG1
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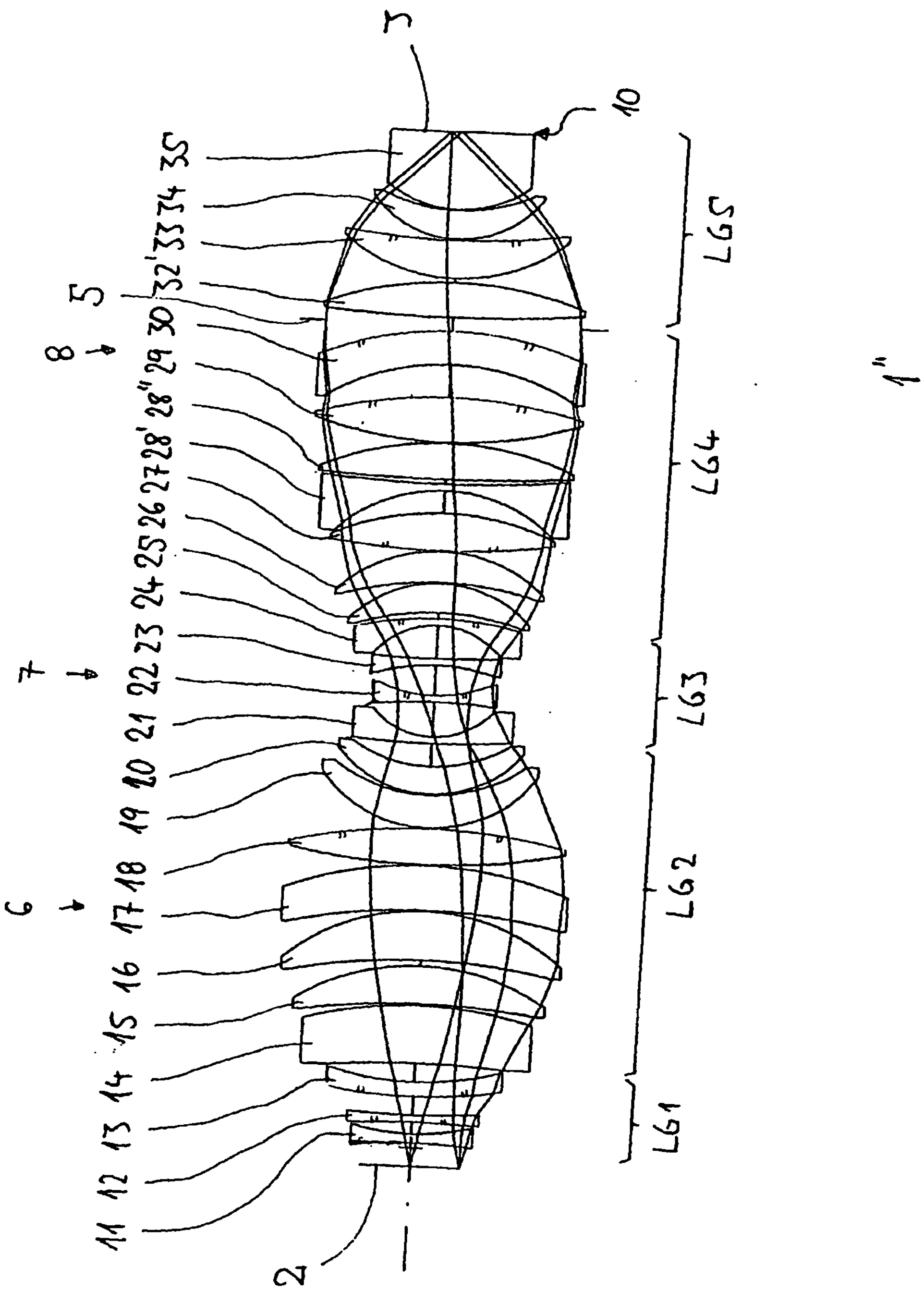
Fig. 2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11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 28' 28'' 29 30 32' 33 34 35
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LG4
LG5

Fig. 3

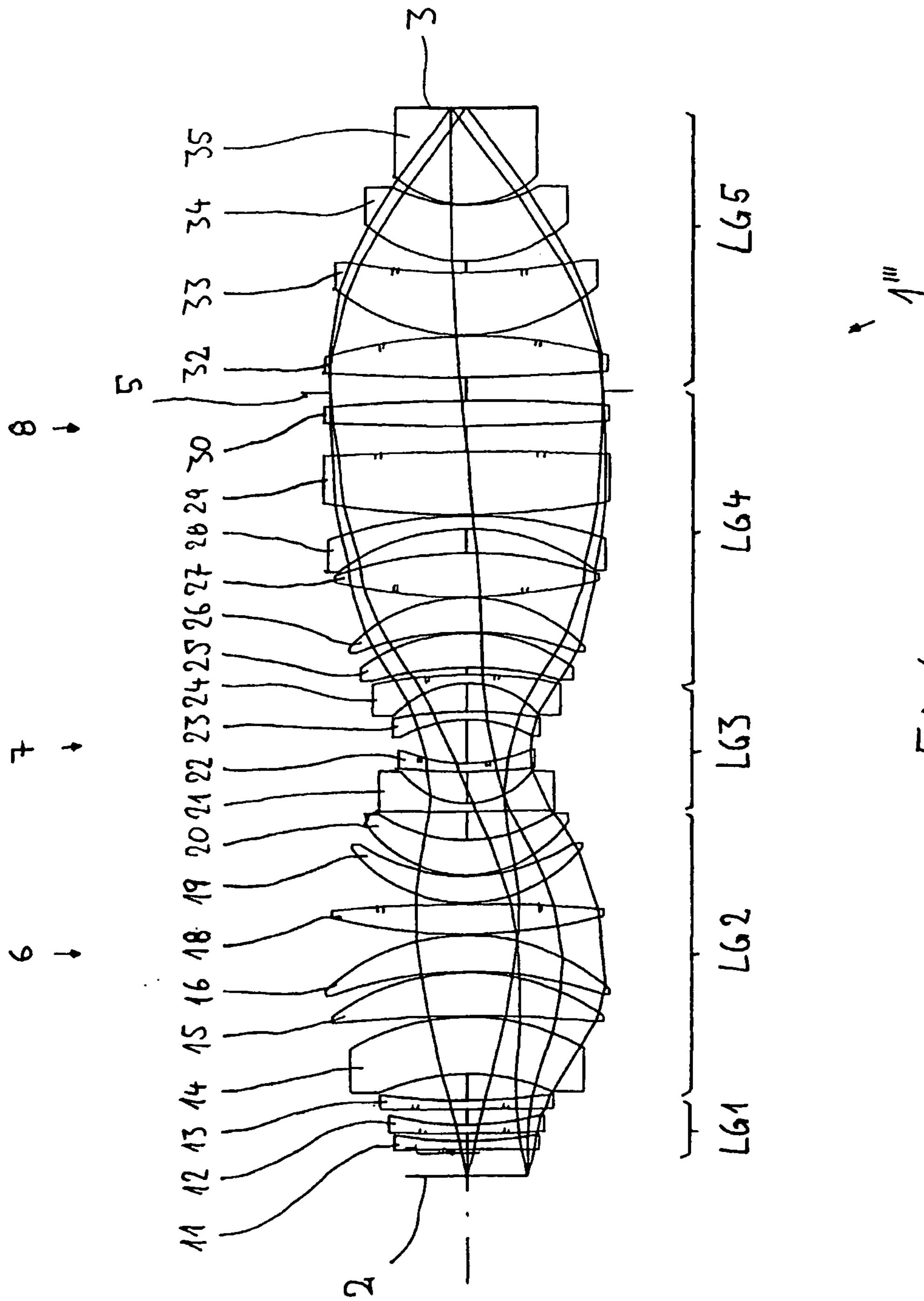
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Fig. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/01954

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G03F7/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

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Y	KAWATA H ET AL: "FABRICATION OF 0.2 MM FINE PATTERNS USING OPTICAL PROJECTION LITHOGRAPHY WITH AN OIL IMMERSION LENS" JAPANESE JOURNAL OF APPLIED PHYSICS, PUBLICATION OFFICE JAPANESE JOURNAL OF APPLIED PHYSICS. TOKYO, JP, vol. 31, no. 12B, PART 1, 1 December 1992 (1992-12-01), pages 4174-4177, XP000415418 ISSN: 0021-4922 abstract ---	1-36

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 July 2003	01/08/2003

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/01954

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

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PCT/EP 03/01954

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